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ANNUAL REVIEW 2012-13

EPSRC Centre for Innovative Manufacturing in INDUSTRIAL SUSTAINABILITY

EPSRC Centre
for Innovative
Manufacturing in
INDUSTRIAL
SUSTAINABILITY

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BACKGROUND AND VISION

Our involvement with the Centre is providing valuable insights for our senior management - access to new ideas and skills that help drive forward our long terms sustainability programs – assistance in understanding what and how other leading companies are achieving their breakthroughs.

Steve Hope
General Manager, Environmental Affairs and Corporate Citizenship, Toyota Motor Europe

This report covers the period July 2012 to 2013 the second year of operation of the EPSRC Centre for Innovative Manufacturing in Industrial Sustainability.

The Centre is one of 16 Centres funded by the EPSRC as part of its Manufacturing the Future theme. It was originally funded with £ 5.2M for 5 years with the aim of carrying out new research into 3 main themes of Industrial Sustainability.

ECO-EFFICIENCY

How to make current products in a low carbon, resource efficient manner (matching industry's short term needs).

ECO-FACTORY

How to transform our factories and products (medium term).

SUSTAINABLE INDUSTRIAL SYSTEMS

How the entire industrial system might change (long term).

The vision of the Centre is to carry out effective research that develops ideas, knowledge and solutions that can be applied to a broad manufacturing community to:

- Drive effective reductions in the use of Materials, Energy and Water
- Develop the social benefits of manufacturing
- Secure strong economic benefits.

We are also building a strong cohort of researchers able to acts as effective leaders for and ambassadors of sustainable change. In all we do we engage with industry to ensure we stay grounded in the realities of business. We support policy makers with the information and insights to enable them to make policy decisions to bring about sustainable evolution.

EXECUTIVE SUMMARY

2012 – 2013 has provided the opportunity to ensure that our early start research programs are bedding down well and starting to deliver valuable results while our mid stage programs have made a strong start. We have been able to continue to build the teams of PhDs, Researchers and Staff so that we now have close to 60 highly skilled and motivated colleagues to enable us to push forward our delivery and growth plans.

SOME OF THE HIGHLIGHTS OF THE PAST YEAR ARE:

First Annual Conference. Our first conference was very well received with strong presentations from many of our industry partners and supporters ensuring a lively set of debates and good industry engagement with many of our first PhD projects and policy work. 95% of attendees said they would recommend us to a colleague.

Interesting tools and test results from the Sustainable Value Project. Forming part of the Eco Factory Grand Challenge, the Sustainable Value project was the first of our projects to get underway and it will conclude in 2014. The Value Mapping tool and archetypes have proved effective with a wide range of company types.

Database of Sustainable Practices. Within the Eco Efficiency Grand Challenge a database of sustainable practices has been developed bringing together diverse sources to provide the basis of a strong tool for manufacturing engineers to draw upon. The development of improved user interfaces and automated input processes promises to make this a very valuable tool.

Growth of the Cohort. Our PhD Cohort has doubled from 11 to 22 and we have another 8 potential starts in October 2013. In addition, we have been able to add 6 Postdoctoral researchers taking our total to 10, while 2 others - Dr Elliot Woolley and Dr James Colwill - have been promoted to lecturer.

Publications. At the same time we have maintained our academic output with 30 papers and reports from our research and 5 book chapters written and/or awaiting publication.

Policy Outputs. We have also led and provided contributions to the UK Government Future of Manufacturing Foresight program and produced a series of White papers and Reports with Lavery Pennell and 2 degrees on the opportunities for business and the UK economy from non-labour resource efficiency.

Introduction of Accessible 'Quick Guides'. We have developed an approach to distil our knowledge and know-how into a format more readily digestible by the manufacturing community. Our Quick Guides series has been developed in response to demand from our industry partners for a document that could be understood by manufacturing engineers without prior knowledge of industrial sustainability practice. The first 12 will appear at the 2013 conference. We expect to expand this to 30 Quick Guides by the end of 2013 and 100 Quick Guides within the next 3 years.

OF ATTENDEES **WOULD RECOMMEND** US TO A COLLEAGUE

OUR PHD COHORT **HAS DOUBLED** FROM 11 TO 22

6
POSTDOCTORAL RESEARCHERS **ADDED** TAKING OUR **TOTAL TO**
10

35
NEW PAPERS, REPORTS AND BOOK CHAPTERS

12
NEW TOOLS AND GUIDES DEVELOPED

These highlights only touch upon the wide range of activities and outputs generated by the Centre in 2013.

We hope that you will find more detail on those that are of particular interest in this report or on our website.

Steve Evans,
Shahin Rahimifard,
Ian Bamford.

August 2013

LEADERSHIP TEAM

A team of experienced academics drawn from the four core Universities leads the Centre. Each has responsibilities both as part of the Executive team and for the research carried out by the staff in their individual University. They bring a depth of experience in their areas of specialisation and in winning and managing research projects and research teams.

Professor Steve Evans
Centre Director
University of Cambridge

Professor Evans has a 20 year record of research and teaching in Industrial Sustainability and led the launch of the UK's first Masters in Sustainable Design. His work on better understanding customer value has led to improved customer understanding processes in leading companies such as Nissan and Jaguar- Land Rover, and is an important foundation for new research into understanding 'sustainable value' in collaboration with VTT Finland & others.

Professor Shahin Rahimifard
Deputy Director and Co-Investigator
Loughborough University

Shahin Rahimifard is Professor of Sustainable Engineering and is the Founder and Director of the Centre for "Sustainable Manufacturing And Reuse/ Recycling Technologies (SMART)". His research work is focused on sustainability issues throughout a 'Product Lifecycle', including projects on sustainable product design, low carbon and energy efficient manufacturing, product service systems, and reuse and recycling technologies. These projects have benefited from involvement of a number of high profile global manufacturers and retailers.

Professor Sir Mike Gregory
Co-Investigator
University of Cambridge

Professor Sir Mike Gregory is Head of the Manufacturing and Management Division of the University Engineering Department and Director of its Institute for Manufacturing which has grown from around 50 to over 230 staff and PhD students. He has held over 15 EPSRC grants most recently two successive IMRC awards. Professor Gregory enjoys excellent international academic links and has served on the UK's Ministerial Advisory Group on Manufacturing as well as numerous institutional, EPSRC and EU committees.

Dr Mike Tennant
Co-Investigator
Imperial College London

Dr Mike Tennant, Lecturer in Business and Environment in the Centre for Environmental Policy, has spent 14 years in the pharmaceutical and biotech sectors. He has extensive experience in early stage commercially-focused exploratory research, international and cross-disciplinary project management and business development.
He is responsible for convening and teaching "Business and Environment" to MBA and MSc students. He researches novel business models that aim to create value in a resource-and-equity-constrained world. He has supervised over 45 research projects.

Dr Peter Ball
Co-Investigator
Cranfield University

Dr Peter Ball is a Reader in Manufacturing Operations, Course Director for the Engineering and Management of Manufacturing Systems and academic lead for the manufacturing and materials Doctoral Training Centre.
His research is in improving production systems with modelling and simulation. Projects include production improvement, systems implementation, supply chain diagnostics and sustainable manufacturing. Notable recent projects are Discrete Event Simulator for Modelling Support Services in an Engineering Environment and Through Life Energy and Resource Modelling (THERM).

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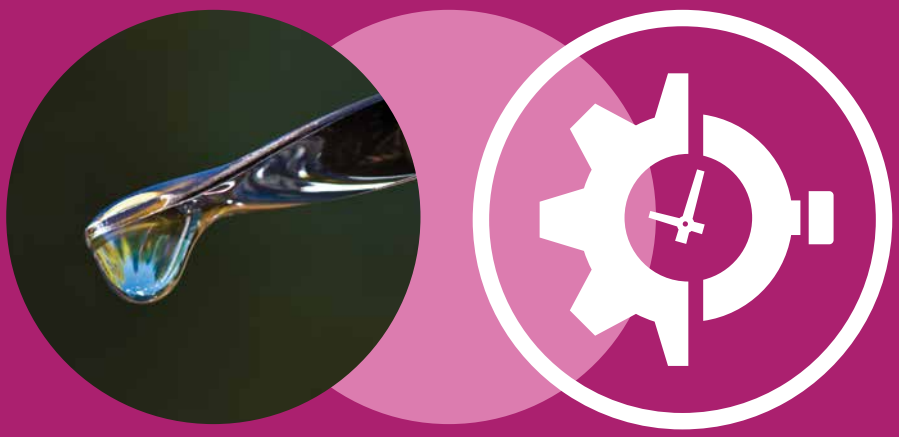


ECO-EFFICIENCY

The ***Eco-efficiency*** grand challenge focuses on developing knowledge and tools to improve manufacturers' sustainability performance without significant changes to product, process or equipment. Performance can vary widely between companies and even between different plant sites in the same company making the same product, and the variation is not fully understood.

GRAND CHALLENGE GC 1.1

ENVIRONMENTAL PERFORMANCE VARIATION (EPV)

What is the range of performance variation between factories, which make similar products with similar technology? We are particularly concerned with understanding why factories which produce the same products vary in sustainability performance, even within the same company. Why does actual environmental performance differ from what may be expected from technical and building specifications? What holds us back from reaching theoretical optimised performance in factories where energy is used to its full potential (taking into account the laws of thermodynamics)? The reasons may be technical, organisational or behavioural, and originate from individual, organisational or industrial histories and scales (e.g. historical thinking/heuristics/rules of thumb). This project seeks to find explication for sustainability performance variation amongst factory sites. We want to identify the factors that clarify differences in performance to gain understanding on ways to remove these barriers. Building on this, we want to build tools and methods to help elevate factory sustainability performance.

Research objectives

- Understand the environmental performance gaps between factories
- Understand how to overcome environmental performance variation and close this gap
- Understand how to encourage quicker, more effective knowledge exchange
- Develop short, medium, and long-term solutions to elevate current factory performance and guide future factory development

PhD Research as part of Environmental Performance Variation

Factory environmental performance management (energy, resources, capabilities)

This research focuses on understanding the possible factors that control environmental performance in production.

Lampros Litos

Sustainable Manufacturing Practices and Performance Variation

Investigating the technical and managerial factors that contribute to certain factories outperforming others in improving resource efficiency.

Simon Roberts

Factory Systems Modelling for Resource Efficiency

This research is focused on defining a framework for factory production, utilities and building architecture systems within simulation models to show what and how resource efficiency can be achieved. The research contributes to the development of environmental performance variation measures and visualisation of performance but is primarily focused within the Eco Factory theme.

Aanand Davé

CONFERENCE PRESENTATION

Bocken, N., Roberts, S., Litos, L., Evans, S. 2013. Understanding environmental performance variation between factories which make the same products under similar circumstances. 7th International Conference on Industrial Ecology (ISIE), 25-18 June, 2013, Ulsan, South-Korea.

JOURNAL PAPER

Bocken, N., Morgan, D., Evans, S. 2013. Understanding environmental performance variation in manufacturing companies. Journal of Productivity and Performance Management. Special issue on performance measurement of sustainable supply chains (forthcoming, October 2013)

Despeisse, M., Ball, P.D. and Evans, S. 2013. "Strategies and Ecosystem View for Industrial Sustainability", In: A.Y.C. Nee, B. Song, S.-K. Ong (Eds.), Re-engineering Manufacturing for Sustainability, Springer, Berlin, pp. 567-572.

PROJECT TEAM

Dr Nancy Bocken
Dr Dai Morgan
Prof Steve Evans
Dr Peter Ball
Dr Mélanie Despeisse
Simon Roberts
Lampros Litos
Aanand Davé

INDUSTRY PARTNERS

Toyota
iema
Carbon Trust
ESKTN
TUC

FUNDING

EPSRC

HOW TO ENGAGE WITH THE EPV TEAM

We would like to speak to more companies, get feedback on tools, and test some of our approaches in your organisation. Please contact Dr Nancy Bocken (nmpb2@cam.ac.uk) or Dr Mélanie Despeisse (md621@cam.ac.uk).

Progress and Outputs

The EPV team is developing a toolkit to assist industry in understanding performance variation, assessing and improving sustainability performance, and learning about industrial sustainability.

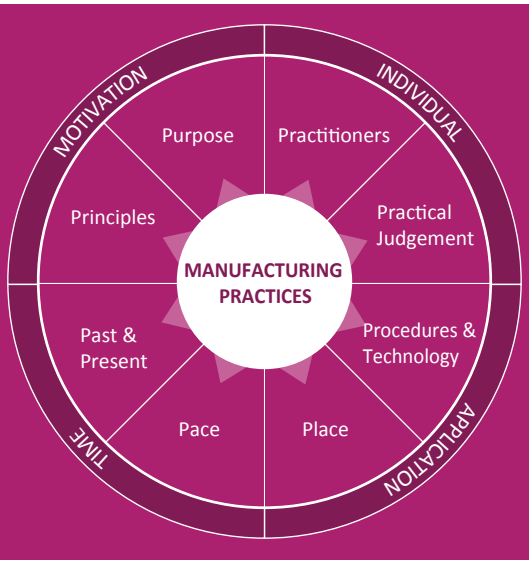
Litos is leading on identifying the leading factors of performance. Simon is working on the library of sustainable manufacturing practices. Aanand is supporting the team on measuring and visualising performance. Although the toolkit is in early stage of its development, the alpha version of the ***EPV toolkit*** is now ready for testing!

Progress in Performance Improvement

Progress has been made in consolidating research on the common technical improvements - actions that raise the performance of equipment and technology - through the development of a website of 900+ sustainable manufacturing practices. Research will continue to explore the managerial, operational and social activities that result in the technical improvements being implemented in various manufacturing environments, so that a richer description of these practices can be developed. Further work will develop approaches to calculate the impact of the practices for comparison across different sites, in relation to different types of performance variation.

A conceptual framework for manufacturing practices has been adopted in this research to help frame the development of a description of each practice. Elements such as information on the type of technology being applied in a given factory setting is as important as the individuals involved, what the purpose (relative advantage) of the practice is and the time period over which the practice is implemented. Through the process of developing a classification for each of these elements and the means to measure the success of each improvement, it is anticipated that comparisons can then be made, resulting in recommendations to tackle performance variation.

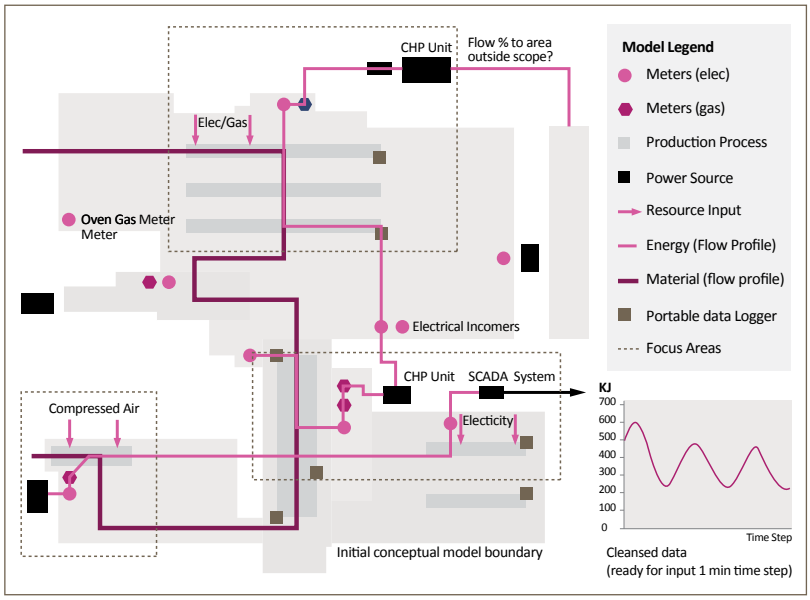
MANUFACTURING PRACTICES



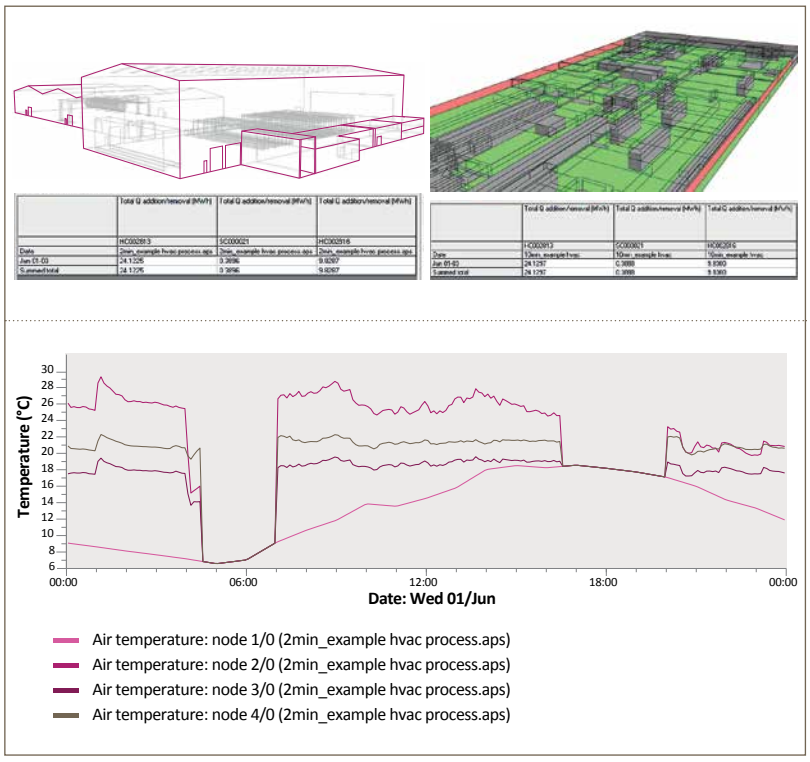
Example of a tool for Performance Assessment

Factory Systems Modelling for Resource Efficiency has the potential to dramatically enhance the potential for energy and material saving measures. Modelling energy and material flows through the factory enables the combined analysis of different data sets across four areas: building architecture, building utilities, manufacturing processes and manufacturing services. Factory models are created in IES<VE> (simulation software) and data composition tables enable a detailed simulation study of both the building architecture and production systems. Those systems are typically analysed in isolation of each other resulting in sub-optimal solutions. This ***Factory Systems Modelling*** approach can support the identification of superior solutions for resource efficiency improvements across all areas of the factory.

Conceptual model showing energy/material flows across system boundary.



Simulation models created in IES<VE>.



OTHER OUTPUTS

Quick Guides will also be produced by end of 2013 and early 2014:

1. *Quick guide on tool database*
2. *Quick guide on sustainable manufacturing practices*
3. *Quick guide on factory performance measures*
4. *Quick guide on factors of performance variation*

PEOPLE INVOLVED

Dan Ayres (MET)

OTHER PEOPLE INVOLVED

Dr Dai Morgan
Dr Claire Barlow
Dr Nancy Bocken
Dr Mélanie Despeisse
Simon Roberts
Aanand Davé

68
THIRD-PARTY TOOLS ANALYSED

STUDENT PROJECTS

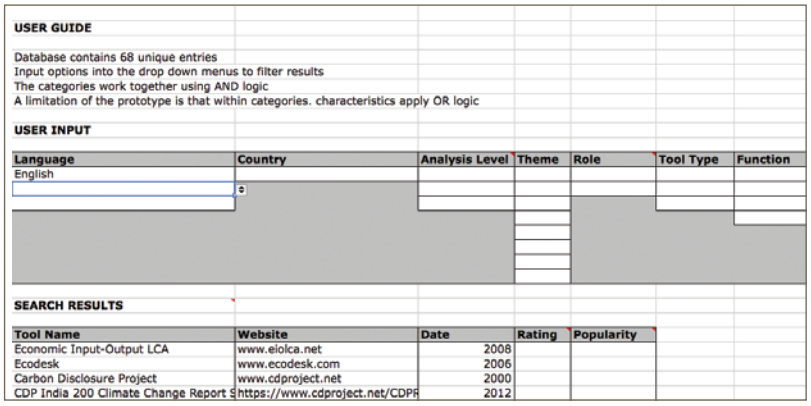
AS PART OF ENVIRONMENTAL PERFORMANCE VARIATION

Review of EPV tools: Increasing uptake and impact of existing resources by improving availability

This project tackled the availability and accessibility of tools in the public domain. There are many free resources tackling issues from industrial efficiency to waste reduction available however they can be difficult to find. Improving availability of these 'tools' might help reduce the variation in performance between firms, as organisations shift towards industry best practice.

After reviewing good practice across different sharing websites, a characteristic based classification system was proposed and a feedback mechanism for reviewing tool content quality were identified.

Prototype of database created in Excel with 68 unique entries



USER GUIDE

Database contains 68 unique entries
Input options into the drop down menus to filter results
The categories work together using AND logic
A limitation of the prototype is that within categories. characteristics apply OR logic

USER INPUT

Language	Country	Analysis Level	Theme	Role	Tool Type	Function
English						

SEARCH RESULTS

Tool Name	Website	Date	Rating	Popularity
Economic Input-Output LCA	www.eiolca.net	2008		
Ecodesk	www.ecodesk.com	2006		
Carbon Disclosure Project	www.cdproject.net	2000		
CDP India 200 Climate Change Report S	https://www.cdproject.net/CDPR	2012		

PROGRESS AND OUTPUTS

- *Physical display tool for eliciting company needs.*
- *A draft mechanism for categorising tools and methods developed by the Centre. (See also PrISMS)*
- *A prototype database for the collection of non-Centre tools, techniques and other useful resources. (See also EPV)*

PUBLICATIONS

Report: Environmental performance variation project: increasing uptake and impact of existing resources by improving availability, MET Long Project, June 2013, Dan Ayres. (See also EPV)

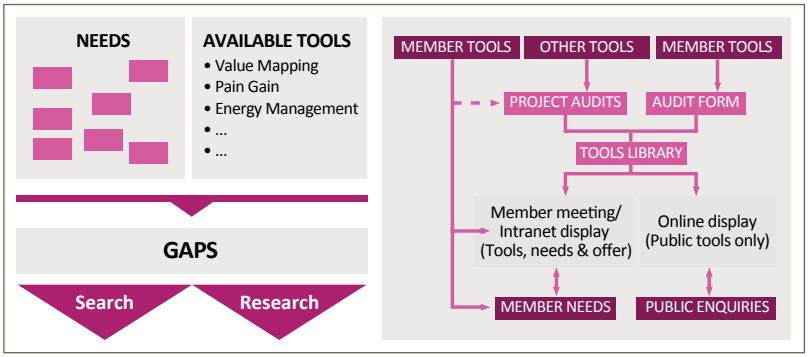
OTHER ECO-EFFICIENCY RELATED PROJECTS

SAKE III

The sustainability assessment and knowledge exchange (SAKE) project incorporates the desire of the EPSRC Centre for Industrial Sustainability to facilitate knowledge exchange between members and the prerogative to actively make the Centre research results available to the membership and beyond. SAKE I and II focused on KPIs and their use within organizations and found that the trade-offs which often arise in performance improvement need to be negotiated within a strong performance management system and need tools and techniques to support the improvement identification and delivery. The SAKE III project develops the recommendations of SAKE I & II. It also extends into the realm of other projects in the Centre – seeking to find ways to develop a mechanism for eliciting and sharing knowledge about the tools and techniques (or lack thereof) for sustainability performance management and performance improvement within companies.

Through consultation within the Centre members internal surveys, and student reviews techniques have been conducted, informing the development of tool sharing mechanisms in the Environmental Performance Variation Project and the development of a tool sharing and elicitation device – with a working prototype to be trialled through Centre - company interactions, and a method of characterizing tools developed within the Centre has been produced to make accessing tools easier. The developments will be trialled and improved over the next year.

SAKE III: Intermediate Tools Vision



SAKE III: Tool Visibility - Library

Meaningful stakeholder dialogue: The need, value and materiality of sustainability reporting*

The Sustainability Assessment & Knowledge Exchange project (SAKE) aims to identify issues and opportunities in the areas of sustainability, Key Performance Indicators (KPIs) and performance metrics and management systems. As part of SAKE, a Centre exercise was conducted to help inform future sustainability reporting at Toyota. The SAKE work triggered Centre interests in how to best engage with external stakeholders in order to identify material issues. Toyota commissioned CIS to start a collaborative project on how material sustainability issues for their future sustainability reports and wider sustainability strategy can be identified.

*This project also feeds into the Sustainable Industrial Systems theme and the SustainValue project.

PrISMS

The Practical and Innovative Solutions for Manufacturing Sustainability (PrISMS) programme is a three-year activity which aims to transform the growth prospects of start-ups and SMEs across the Eastern Region – creating and safeguarding jobs many more, whilst helping companies make their products and operations more sustainable.

Research from Centre projects is fed into the programme to help integrate sustainability considerations into interventions. Already, tools for eco-ideation, value mapping and pain-gain evaluation have been delivered into companies, with many more interventions planned and tools being developed.

The PrISMS programme is delivered by experienced facilitators all of whom have worked in manufacturing at a senior level for many years and have supported hundreds of start-ups and SMEs. It is designed to require as little time as possible from the company's management and to ensure that knowledge and skills are transferred to the companies involved, enabling them to build capabilities in key areas of the business.

Currently 47 companies are enrolled in the scheme, with interventions begun with 39 SMEs and 9 ESVs. Overall the scheme hopes to reach 50 ESVs and 70 SMEs.

OTHER PHDS ASSOCIATED WITH ECO-EFFICIENCY

Eco-efficient production system design

The aim of this research is to understand how to design production systems to be eco-efficient (to use less material, energy, water, etc) in addition to achieving the cost, quality and delivery objectives. The work will develop a specification for an eco-efficient production system design methodology, develop the methodology and appraise how eco-efficiency requirements trade-off with economic objectives in system design.

Yu Chen

PEOPLE INVOLVED

Ian Bamford, Dr Bernhard Dusch (IfM-ECS), Dr Dai Morgan

OTHER PROJECTS INVOLVED

Environmental Performance Variation

FUNDING

EPSRC

OUTPUTS

Materiality Matrix: An approach to help identify material sustainability issues of a business.

PROJECT TEAM

Stefan Hemel
Dr Nancy Bocken
Dr Padmakshi Rana
Fenna Blomsma
Litos Lampros
Simon Roberts

OUTPUTS AND PUBLICATIONS

Trade Press Article – Sustainability: *It's not easy being green, especially for SMEs, The Manufacturer, March 11th 2013, Morgan. D.C. http://www.themanufacturer.com/articles/sustainability-its-not-easy-being-green-especially-for-smes/*

Interim progress report, ERDF12/054

PEOPLE INVOLVED PARTNERS

IfM-ECS Consultancy Ltd.
Ecopare Ltd
Essex County Council

TO FIND OUT MORE ABOUT PARTICIPATING IN THE PROGRAMME CONTACT:

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Or find more details at: http://www.ifm.eng.cam.ac.uk/services/prisms/

ANNUAL REVIEW

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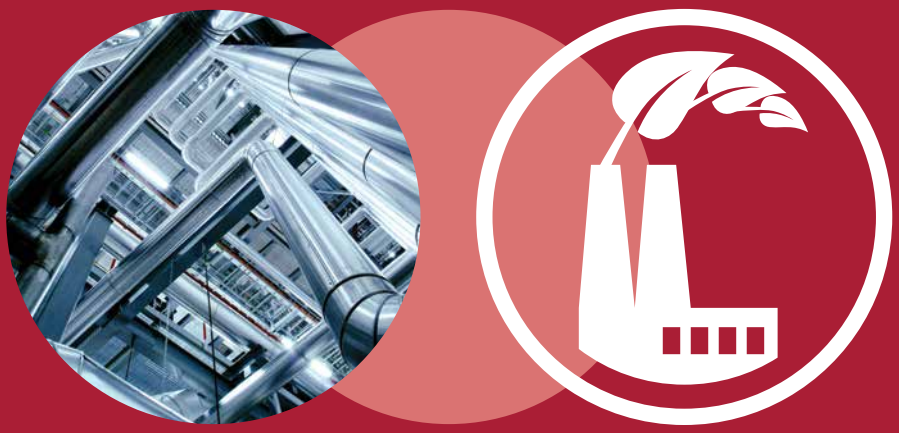


ECO-FACTORY

Eco-Factory seeks to improve our knowledge and tools for integrating the various life cycle dimensions of product-process-plant design and operation. This is the largest research agenda and covers base knowledge to technology and application, across all manufacturing stages of the design-make-use/serve value chain.

GRAND CHALLENGE 2.1

RESOURCE EFFICIENT MANUFACTURING

The principle of "doing more with less" in an increasingly resource constrained future is fundamental to sustainable development and central to the manufacturing industry's ability to meet future demand. There is a growing realisation that increasing consumption patterns are unsustainable with a limited global material reserve and increasing demand for scarce resources is in turn not only increasing prices, but the need for radical improvements in the efficient use of materials. Existing tools and approaches to examine resource flows do not identify and support efficiency improvement options and manufacturers need support with decision making to enhance resource efficiency.

This project is investigating Resource Efficient Manufacturing (REM) and use the acquired knowledge to develop proactive methodologies, technologies and tools to support substantial resource efficiency improvements across the manufacturing sector. The research scope of this project is focused on manufacturing processes, systems and supply-chains, and how these can be made more efficient through improved management, methods and technologies. The resources considered are limited to those resources that are fundamental to manufacturing, and whose current and future use is most likely to have the greatest environmental impact: Water, Energy and Materials within factory. Water and energy minimisation tools have already been developed by researchers at Loughborough's SMART Centre. These tools together with a new Materials Efficiency Tool will ultimately be combined to create a single integrated 'resource efficiency dashboard'.

The project will fully address the complexity of material flow, to assist selection and implementation of existing strategies including dematerialisation, material elimination, material substitution, and process or production optimisation. Technologies to enable accurate measurement, management and control of resources will be developed and industrial case studies will be incorporated to validate tools.

Therefore the three key research questions addressed in this project are as follows:

1. How might existing technologies and processes be improved and which future/ high-tech materials have the potential to enter manufacturing and how may they increase resource efficiency?
2. How can material flow be measured and modelled in a way that facilitates improved decision making in product manufacturing?
3. What KPIs can be used in support of current material efficiency approaches and how might they be generated or defined?

PLANNED OUTPUTS

Over the next 12 months the planned mini-project outputs are to include reports, conference and journal papers, alongside material flow modelling tool and KPI selection tool definitions and demonstrations of technology solution concepts.

EARLY PROGRESS

Initial literature review has identified shortcomings in current material efficiency techniques and material flow assessment and modelling tools.

A concept framework for material efficiency has been designed and described in a position paper, in preparation for publication.

PROJECT TEAM

Dr Oliver Gould
Dr James Colwill
Professor Shahin Rahimifard
PhD (start Oct 13)

INDUSTRY PARTNERS

Toyota
Unilever

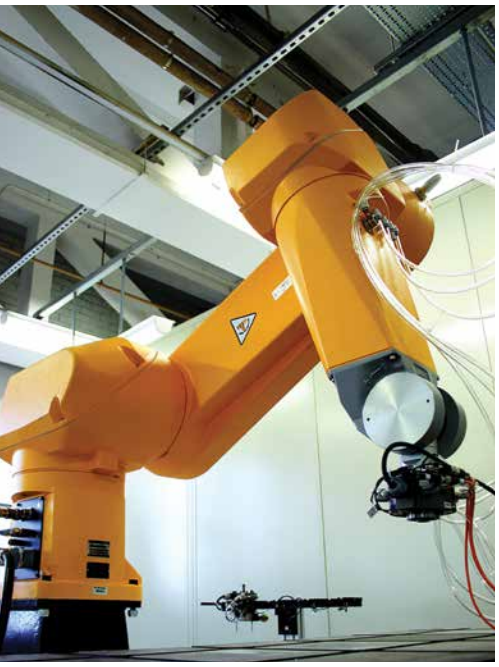
FUNDING

EPSRC

HOW TO ENGAGE WITH THE REM TEAM

If you would like to learn more about this grand challenge project or have industry-relevant ideas for research that you wish to discuss please contact Dr Oliver Gould (o.j.gould@lboro.ac.uk).

Alternatively, if you wish to become actively involved in this research grand challenge, please contact Dr James Colwill (j.a.colwill@lboro.ac.uk).

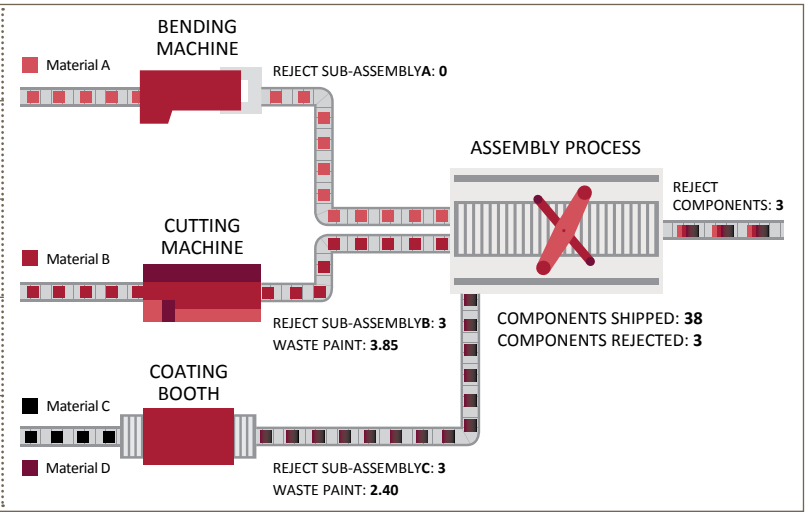


In order to answer these questions, the GC has been divided into several sub-projects, each one aiming to answer the specific requirements of the challenges in the REM project. The first three sub-projects include:

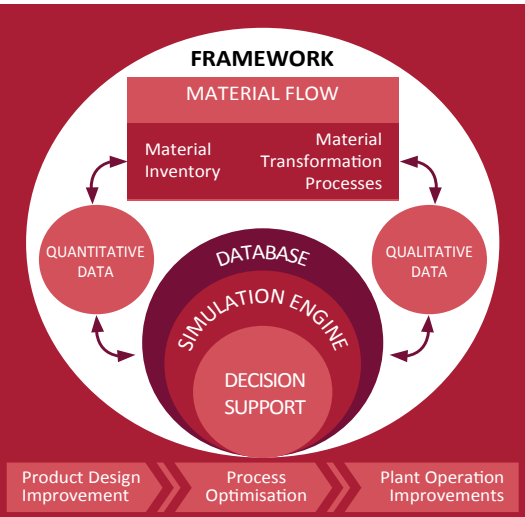
1. **Resource Efficiency Technologies:** this is approached with broad perspective of technology solutions or future potential material substitutions that can be applied across a range of products or processes, illustrated with case studies or prototypes where possible.
2. **Dynamic Material Flow Modelling:** addresses the lack of proactive support provided by existing tools in identifying potential material efficiency improvements. The project will approach material flow modelling to enable identification of opportunities for improved efficiency, with simulation of alternative production scenarios and assessment of these to support decision making. The proposed approach considers 'material transformation' as a key factor in modelling material flow from the perspective of identifying possible efficiency improvements.
3. **KPI Definition and Selection:** focuses on defining which KPIs are currently used to measure resource efficiency within manufacturing and how these differ from sector to sector, or Company to Company. The work will look specifically at the definition of KPIs that can effectively describe material efficiency when employing various strategies (material elimination, material substitution and dematerialisation). A tool will support the selection of the most critical sector-specific or company-specific KPIs in the context of material efficiency strategies employed.

Material flow model of a simple production system

	Bending Machine	Cutting Machine	Bending Machine	Bending Machine
Total Processing Time (min)	315.00	398.00	396.00	348.00
Assemblies Accepted (no.)	188	192	118	110
Quality Control Waste (no.)	23	8	15	7
Process Waste (kg)	0	10.00	6.65	0



CONCEPT FRAMEWORK FOR MATERIAL EFFICIENCY



GRAND CHALLENGE 2.2

ZERO WASTE – ZERO EMISSIONS

Many companies have taken on board the challenge to reduce waste and emissions with respect to their manufacturing activities due to a number of financial and legislative initiatives and strategies. These endeavours are generally focused on the most cost effective solutions for reduction of waste and emissions, without fully understanding their wider life cycle impact. This project aims to investigate methods, tools, technologies and processes required to support the long term goal of Zero Waste Zero Emission (ZWZE) by manufacturing industry, whilst ensuring that environmental impacts of waste and emission management activities over their entire life cycle are understood and reduced. The project will extend the scope of waste flow modelling from various processes within a manufacturing facility to include the related activities at supply chain level. This will ensure that ZWZE is not achieved simply by the displacement of detrimental impacts to upstream and/or downstream processes. In addition, a range of novel recycling technologies required to deal with complexity in material mix with modern products are also investigated. Finally, the project will also explore appropriate methods for developing 'Key Performance Indicators' required to support principle decisions in the management of waste throughout the entire supply chain of a product.

Therefore, the three key research questions addressed in this project are as follows:

1) How can waste generation associated to a product (or a component within a product) can be modelled and monitored across the entire supply chain?
2) What are the simple and cost effective assessment methods for measuring the life cycle impact of current waste management practices?
3) What are the future recycling technologies required to deal with emerging complexity in design and material contents of modern products?

In order to answer these questions, the GC has been divided into several sub-projects, each one aiming to answer the specific requirements of the challenges in ZWZE project. The first three sub-projects include:

1. Future recycling technologies: this focuses on applications where the use of more sensitive materials such as Rare Earth Elements (REE), Strategically Important Metals (SIM) and composites etc. These materials have highlighted a need for new recycling technologies for future products.
2. Waste Flow Methodologies: to deal with the issue of waste generation associated with a specific product or component, this is being investigated across a supply chain rather than in isolation in a factory so that the full impact of a products waste can be assessed.
3. Development of appropriate KPIs: to support selection of most appropriate waste management options, with the core concept of 'not every waste management option is environmentally or economically sound', investigations are looking at the actual environmental and economic sense of current waste management options.

PLANNED OUTPUTS

Over the next 12 months the planned outputs for these sub-projects will be a number of reports and guidelines as well as a conference and journal paper, a number of technologies, including separation of REE and SIM aimed at forming a pre-concentration waste stream, and a computer modelling tool for measurement of waste across a supply chain.

EARLY PROGRESS

Literature Review to identify gaps in current waste management technologies and processes

Initial Guideline on 'solid' waste management options for small, medium and large manufacturers

Prototype of solid dense media separator

PROJECT TEAM

Professor Shahin Rahimifard
Dr Michael Barwood
Leila Sheldrick
PhD (start Oct 13)

INDUSTRY PARTNERS

Toyota
Unilever
WRAP
ESKTN

FUNDING

EPSRC

HOW TO ENGAGE WITH THE ZW-ZE TEAM

If you would like to learn more about this grand challenge project or have industry-relevant ideas for research that you wish to discuss please contact Dr Michael Barwood (m.barwood@lboro.ac.uk).

Alternatively, if you wish to become actively involved in this research grand challenge, please contact Professor Shahin Rahimifard (s.rahimifard@lboro.ac.uk).

PLANNED OUTPUTS

These sub-projects will yield the first significant results which will include a well-defined and demonstrated technology-based methodology for monitoring machine tool wear, which will be reported via journal publication. In addition, a set of environmental key performance indicators, with relevant methodologies to incorporate them in inventory planning, will be developed and presented.

EARLY PROGRESS

Despite the short period for which the project has been running, promising results have been generated for the correlation between thermographic signal and machine tool wear. In addition an initial framework for an Intelligent Sustainability Balanced Scorecard has been developed.

PROJECT TEAM

Dr Alessandro Simeone, PhD (start Oct 13)
Dr Elliot Woolley
Professor Shahin Rahimifard

INDUSTRY PARTNERS

Unilever
GM
Carbon Trust
ESKTN

FUNDING

EPSRC

HOW TO ENGAGE WITH THE ECO-INTELLIGENT FACTORY TEAM

If you would like to learn more about this grand challenge project or have industry-relevant ideas for research that you wish to discuss, please contact Dr Alessandro Simeone (a.simeone@lboro.ac.uk).

Alternatively, if you wish to become actively involved in this research grand challenge, please contact Dr Elliot Woolley (e.b.woolleya@lboro.ac.uk).

GRAND CHALLENGE 2.3

ECO–INTELLIGENT FACTORIES

Current manufacturing management systems and related decision making are optimised for cost effectiveness, time efficiency (output) and quality control. These complex networks of data and information systems enable manufacturers to remain competitive by making informed short-term decisions and by forecasting over longer time scales. However environmental considerations are not comprehensively included in this planning, and it is becoming clear that their inclusion would be beneficial due to increasing demands and pressures from both governments and customers, and for the preservation of resources, and potential cost avoidance.

To address this need, this project is developing industry-relevant methods and tools to enable the inclusion of environmental considerations within manufacturing planning, control and management. It will generate both smart technologies and data infrastructures that collect and process relevant information about key environmental impacts associated with a range of manufacturing decisions to reduce the overall environmental impact of manufacturing activities. Furthermore, environmental impact management support tools, which utilise this generated information will be developed to ensure that evolving business strategies are implemented whilst considering and minimising these impacts.

Research questions

- What technologies need to be developed to generate real-time information to support eco-aware decision making?
- Which metrics are required to support environmentally focused manufacturing decisions across a range of management and planning activities?
- How is it possible to achieve an intelligent sustainable management and control system for long-term business decision making?

Sub-projects

Tool State Identification via Infrared Monitoring, Signal Processing and Neural Network Pattern Recognition

This project identifies the correlation between thermographic signals acquired by using an IR camera and the tool wear in milling processes on aluminium to generate an intelligent system that determines the most appropriate schedule for tool replacement to minimise related environmental impacts.

Advantages: *defects reduction, energy saving, automation failure prevention, surface integrity preservation, cutting parameters optimization, production scheduling improvement*

Environmental Impact Assessment in Inventory Management

Procedures for integrating sustainability aspects into the factory level decision making are being developed to define relevant KPIs for a sustainable inventory assessment in terms of quantities, storage, transportation and efficiency.

Advantages: *Intelligent inventory optimization, unitary environmental impact evaluation*

Intelligent Sustainability Balanced Scorecard

In order to translate business plans into actions, a strategic management tool, the Intelligent Sustainability Balanced Scorecard, will be implemented through advanced analytical methodologies and intelligent decision making support to achieve an eco-aware control system able to balance financial, technological and sustainability aspects.

Advantages: *Performance evaluation and forecasting, holistic environmental impact management, long-term sustainable decision making*

GRAND CHALLENGE 2.4

SUSTAINABLE VALUE CREATION FOR MANUFACTURING NETWORKS

2011 2012 2013 2014 2015 2016 2017

SustainValue is a collaborative research project on new industrial models for a sustainable and efficient production. It is funded (Apr 2011 – Mar 2014) by the European Commission's Seventh Framework Programme (FP7). The EU collaboration consists of six research and four industrial partners.

The increasing demands for sustainability have created new challenges as well as emerging opportunities for society and business. Companies need to be pro-active in thinking about the opportunities sustainability will present to develop new products and markets and optimize their value networks. Based on this premise, the overall goal of the SustainValue project is to develop industrial models, solutions and performance standards for sustainable production and service networks with the inclusion of a broader range of stakeholders in the value network.

The EPSRC Centre for Innovative Manufacturing in Industrial Sustainability is leading the work on 'business models in sustainable manufacturing value networks' within SustainValue (Work Package 2). The research seeks to develop a sustainable business modelling process and a portfolio of tools to deliver environmental, social and economic value based on an industrial system view.

Research objectives:

- Learning what is needed to describe and better implement sustainable business models.
- Creating an architecture for business models that encourages a full exploration of the implications of sustainability.
- Understanding multiple stakeholder views in defining value and understanding the implications of emerging value networks.
- Design and develop tools that companies can use to describe their current business models and explore new ones that deliver sustainability.

Progress and Outputs

The project is in its final year and is currently at the test and use phase. The work has involved a review of academic and grey literature and industrial practice (case studies) on business models, business modelling and value networks, and more specifically innovative business models for sustainability. Multiple workshops and continuous discussions, with

PROJECT TEAM

Prof Steve Evans
Dr Padmakshi Rana
Samuel Short

Dr Nancy Bocken
Dr Dai Morgan
Miying Yang
Lloyd Fernando

EPSRC INDUSTRY PARTNERS

Riversimple
Toyota
WRAP
iema
TUC

EU INDUSTRIAL PARTNERS

CLAAS (DE)
ELCON Solution Oy (FI)
FIDIA (IT)

FUNDING

EU Framework Programme 7

HOW TO ENGAGE WITH THE SUSTAINVALUE TEAM

We would be keen to speak to companies who are seeking to explore their current and/or new business models for sustainability, engage in knowledge exchange and discussions, conduct workshops to test our approach and tools and receive feedback.

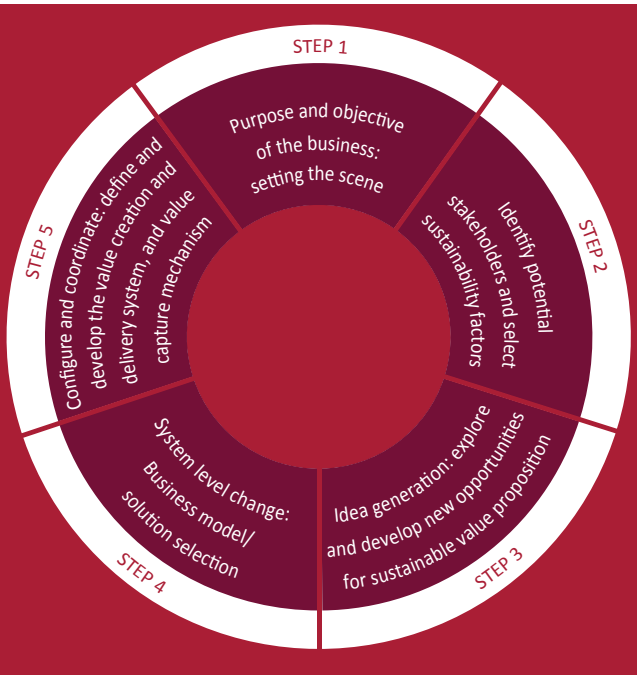
Please contact Dr Padmakshi Rana (pr296@cam.ac.uk).

companies ranging from start-ups to multinationals and researchers across Europe and industrial stakeholders, were and are being conducted to test the process and tools developed and gather feedback for improvement. Outputs to date include the following:

- Sustainable business modelling process is a five step approach that considers a network-centric perspective to deliver sustainability. It will assist companies in the analysis and design of sustainable business models.

SUSTAINABLE BUSINESS MODELLING PROCESS

(Rana et al. 2013)

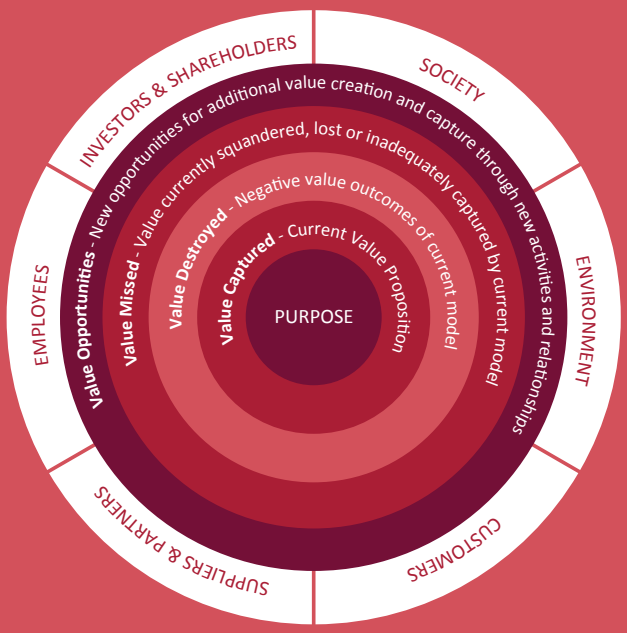


- **Tools for sustainable business modelling:**
  - ***Value mapping tool*** assists in mapping various forms of value and analyzing exchanges from a multi-stakeholder perspective across the industrial network. It assists organisations in stimulating innovation and creating new sustainable value propositions.

VALUE MAPPING TOOL

(Adapted from Short et al. 2012, further developed in Bocken et al. 2013)

Populated Value Mapping Tool



- Sustainable business model archetypes describe groupings of mechanisms and solutions that might contribute to building up the business model for sustainability. The archetypes assist practitioners in transforming new sustainable value propositions, while designing sustainable business models.
- Tools developed by the other SustainValue consortium partners that support sustainable business modelling include – sustainability impact calculation tool and life cycle cost estimation tool.

- Case study narratives exemplifying current industrial practice in business models and/ for sustainability

*The findings and output from the SustainValue project are being used and extended to inform the research carried out in the Sustainable Industrial System project on developing an **'understanding of industrial systems, sustainability and the delivery of systemic change'.***

PhD research as part of Sustainable Value Creation

Sustainable Business Model Transformation

Exploring the extent to which existing business models for sustainability might deliver real long-term triple-bottom-line sustainability and the implications this might have for industrial policy at the national and global level.
Samuel Short

Design of Sustainable Product-Service Systems for Industrial Symbiosis

Investigating the potential of Product-Service Systems (PSS) exchange among manufacturing companies as a strategy of achieving sustainability in the context of industrial symbiosis, more specifically, by exchanging tangible and intangible waste. Progress to date includes development of a value analysis tool to help companies create value from other companies' waste by delivering PSS.
Miying Yang

Student projects as part of Sustainable Value Creation

Exploring socio-political and economic drivers, mechanisms and barriers in designing sustainable business models

This project explored socio-political and economic drivers, mechanisms and barriers in designing sustainable business models and developed an integrated framework. The research involved a literature review and case studies of five organizations across manufacturing, finance and academia.

PEOPLE INVOLVED

Simon Wolf
Dr Claire Barlow
Dr Padmakshi Rana

Using Environmental Cost-Benefit Analysis to Assess Industrial Symbiosis Projects

The project explores the use of business assessment tools to see how these support or inhibit the initiation of industrial symbiosis based business models.

PEOPLE INVOLVED

Anton Thorolfsson
Samuel Short

SUSTAINABLE VALUE CREATION PUBLICATIONS

WORK PACKAGE
2
REPORTS

Work Package 2 Reports (available at: http://www.sustainvalue.eu/publications.htm)

- Rana, P., Short, S.W. and Evans, S. 2013 'First stage prototype tools and methods, capable of being fully used by industrial partners.' *(under review)*
- Rana, P., Short, S.W. and Evans, S. 2012 'State-of-practice in business modelling and value-networks, emphasising potential future models that could deliver sustainable value.'
- Rana, P., Short, S.W. and Evans, S. 2012 'Report on gap analysis in business modelling and value-network tools and methods against future needs.'
- Holgado, M., Macchi, M. and Corti, D. 2012, 'Proposed design of new methods and tools, within the overall architecture.'

Journal Papers

- Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2013, 'A value mapping tool for sustainable business modelling', Corporate Governance,Vol. 13, No. 5.
- Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2013, A literature and practice review to identify Sustainable Business Model Element Archetypes, Journal of Cleaner Production. (under review)
- Valkokari, K., Valkokari, P., Palomäki, K., Uusitalo, T., Reunanen, M., Macchi, M., Rana, P. and Liyanage, J.P. 2013 'Road-mapping the business potential of sustainability within the manufacturing industry', Foresight. (accepted manuscript, awaiting publication)
- Yang, M., Rana, P. and Evans S. 2013, 'Product Service System (PSS) Life Cycle Value Analysis for Sustainability', Journal of Remanufacturing. (submitted)

Conference Papers

- Rana, P., Short, S.W., Bocken, N.M.P. and Evans, S. 2013, 'Towards a Sustainable Business Form: A Business Modelling Process and Tools', Sustainable Consumption Research and Action Initiative (SCORAI) Conference: The Future of Consumerism and Well-Being in a World of Ecological Constraints, 12th -14th June, Clark University, Worcester, USA.
- Yang, M., Rana, P. and Evans S. 2013, 'Using Value Analysis to Drive Sustainable Product-Service System (PSS)', Proceedings of The Spring Servitization Conference 2013: Servitization in the multi-organisation enterprise (ISBN: 978 19058 66656), 20th - 21st May, Aston Business School, Birmingham, UK.
- Yang, M., Rana, P. and Evans S. 2013, 'Product Service System (PSS) Life Cycle Value Analysis for Sustainability', The 6th conference on Design and Manufacture for Sustainable Development, 15th -17th April, Zhejiang University, Hangzhou, China.
- Short, S.W., Rana, P., Bocken, N.M.P., Evans, S. 2012, 'Embedding Sustainability in Business Modelling Through Multi-stakeholder Value Innovation', in Emmanouilidis, C, Taisch, M and Kiritsis, D (eds), IFIP Advances in Information and Communication Technology (IFIP AICT, Series ISSN: 1868-4238), Competitive Manufacturing for Innovative Products and Services: Proceedings of the APMS 2012 Conference, Advances in Production Management Systems.
- Holgado, M., Corti, D., Macchi, M., Rana, P., Short, S.W. and Evans, S. 2012, 'Business modelling for sustainable manufacturing' in Emmanouilidis, C, Taisch, M and Kiritsis, D (eds), IFIP Advances in Information and Communication Technology (IFIP AICT, Series ISSN: 1868-4238), Competitive Manufacturing for Innovative Products and Services: Proceedings of the APMS 2012 Conference, Advances in Production Management Systems.
- Short, S.W., Bocken, N.M.P., Rana, P., Evans, S., 2012, 'Business Model Innovation for Embedding Sustainability: A Practice-Based Approach Introducing Business Model Archetypes', Proceedings of the 10th Global Conference on Sustainable Manufacturing (GCSM): Towards Implementing Sustainable Manufacturing, 31st October - 2nd November, Istanbul, Turkey.

Upcoming Conference Paper:

- Valkokari, K., Rana, P., Short, S.W., Bocken, N.M.P. and Valjakka, T. 2013, 'Mapping multi-stakeholder value for sustainable business model innovation – a study of the Finnish furniture industry', 14th International CINet Conference: Business Development and Co-creation, 8th - 11th September, Nijmegen, Netherlands.

Conference Presentations and Posters

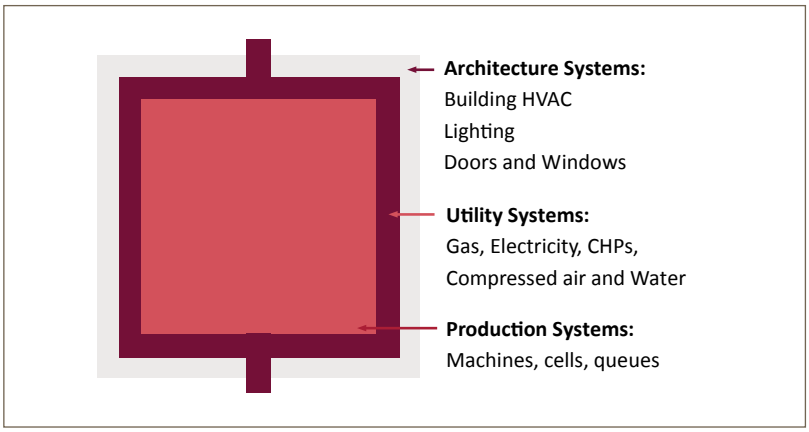
- Bocken, N.M.P., Short, S.W., Rana, P. and Evans, S., 2013, 'The use of business model archetypes to stimulate corporate innovation towards sustainability', 7th International Society for Industrial Ecology (ISIE) Biennial Conference - Industrial Ecology: Strategy for Green Economy, 25th -28th June, University of Ulsan, Ulsan, South Korea.
- Short, S.W., Bocken, N.M.P., Rana, P. and Evans, S., 2012, 'Business model innovation for sustainability: A practice-based approach for the manufacturing sector', International Society for Industrial Ecology (ISIE) Gordon Research Conference, June, Switzerland.
- Bocken, N.M.P., Short, S.W., Rana, P. and Evans, S. 2012, 'Sustainable Business Modelling: a practical approach', International Society for Industrial Ecology (ISIE) Gordon Research Conference, June, Switzerland.

PHD RESEARCH PROJECTS ASSOCIATED WITH ECO-FACTORY

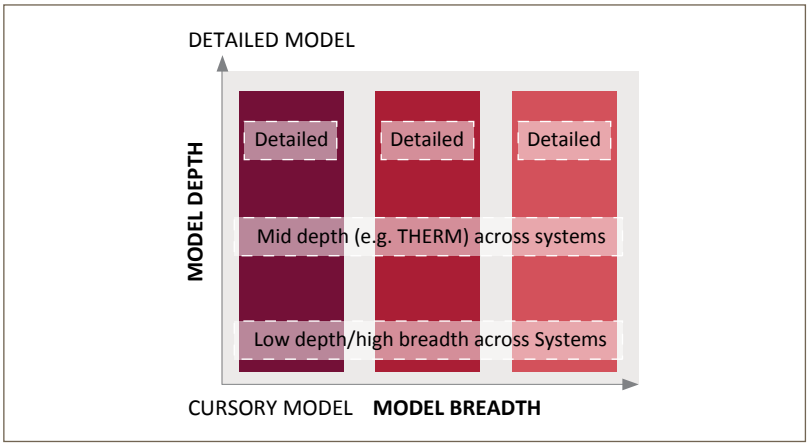
Factory Systems Modelling for Resource Efficiency

This research is focused on defining a framework for factory production, utilities and building-architecture systems within simulation models to show what and how resource efficiency can be achieved. Specifically, the research will understand what the impact of simulation model depth and breadth has on result outputs and how decision-making ability is affected. The figures below show how the factory sub-systems inter-relate and the variation of modelling detail and breadth for those sub-systems.

Relationship of factory sub-systems



Model Breadth Vs. Model depth



This work also contributes to the development of environmental performance variation measures and visualisation of performance.

Eco-effective Changeovers; Underpinning the Capabilities

Understanding the impacts from the changeover processes within the manufacturing environment and researching ways to achieve zero waste changeover capabilities.
To date attention has only been given to the time and cost dimensions of changeovers. However, some activities during changeovers such as cleaning, cause noticeable waste streams especially in highly frequent cases. Additionally, considering the movement towards customized products, more frequent changeovers will be needed and, therefore, preventing or minimizing the impacts from changeover processes will be critical for industrial sustainability.
Ergun Grungor

OUTPUTS

Two Quick Guides

1. *Factory Modelling Quick Guide part of a three guide series on Resource Efficient Factory Modelling. A series of quick guides defining data composition, model building and simulation of energy and material resource efficiency opportunities.*

2. *Introduction to Resource Efficient Manufacturing Quick Guide another part of three guide series on Resource Efficient Factory Modelling.*

PUBLICATIONS

Ball, P.B., Davé A., 2013, Requirements for an eco-efficient production system design methodology, Proceedings 11th Global Conference on Sustainable Manufacturing, September 23 – 25, Berlin, Germany

Davé A., Ball, P.B., 2013, Factory Modelling: Data Guidance for Analysing Production, Utility and Building Architecture Systems, Proceedings of the 11th International Conference on Manufacturing Research (ICMR2013) , September 2013, Cranfield, UK.

Davé A., Oates, M., Turner C., Ball P.B., 2013, Factory Modelling: The Impact of Granularity and Quality on Production and Building Architecture System Simulation Outputs, International Journal of Systematic and Evolutionary Microbiology (IJSEM), ***In review.***

TEAM

Aanand Davé
Dr. Peter Ball,

INDUSTRY PARTNERS

Luxottica
Airbus
Toyota

FUNDING

EPSRC

SUSTAINABLE INDUSTRIAL SYSTEMS

The ***sustainable industrial systems*** grand challenge/theme looks at the changes that need to be made to deliver an industrial system that produces 80% less greenhouse gas emissions and uses 75% less material resource.

GRAND CHALLENGE PROJECT 3.1

CONFIGURATIONS FOR SUSTAINABLE INDUSTRIAL SYSTEMS

2011 2012 2013 2014 2015 2016 2017

Concepts such as the circularity, systems thinking and whole system design provide compelling principles on which future industrial systems might be built. However there is a lack of practical understanding of what skills, capabilities, practices and tools are required for manufacturing firms to be able to support the delivery of these visions.

Inspired by these concepts, this project seeks to develop and explore configurations – descriptions of what gets made where and how – that might form part of the sustainable industrial systems of the future. The project relies on practical engagement with companies, tackling their real world problems to develop an understanding of the challenges companies face and the tools that might help.

At the same time our research seeks a deep understanding of the context in which configurations will be deployed, and the role of the firm as an agent of change in transitions towards sustainability.

By exploring the implications of these possible configurations we aim to help companies (and other actors) understand what is needed to deliver the sustainable industrial systems of the future.

Research objectives:

- Understand how a consideration of sustainability changes the planning process for manufacturing firms.
- Understand the firm's role in improving sustainability performance.
- Understand what enablers are needed to unlock system performance.
- Understand what might get made where and how in a sustainable industrial system.

PhD Research as part of Configurations for sustainable Industrial Systems

Stimulating the adoption and diffusion of sustainability driven radical innovation within and across businesses

How can businesses be stimulated to innovate together and how can the goals for the innovation process be aligned? The focus is on innovations that goes beyond eco-efficiency to major and radical innovation (new business models, different means of production, etc).
Fenna Blomsma

Developing business models for a closed-loop economy

This research extends the concept of "loops" or cycling of material and energy flows to social systems through the exploration of non-material flows between organizations within a business ecosystem and how this could provide insight on unleveraged opportunities for delivering value across the system.
Geraldine Brennan

PROJECT TEAM

Dr Mike Tennant
Dr Dai Morgan
Dr Nancy Bocken
Prof Steve Evans
Prof Sir Mike Gregory
Dr Ritsuko Ozaki
Dr Melanie Despeisse
Dr Jae-Hwan Park
Dr Padmakshi Rana
Sotirios Levakos
Fenna Blomsma
Ilka Weißbrod
Jules Saunderson
Geraldine Brennan
Sudhir Rama Murthy
Lloyd Fernando
Yuan Tao
Stefan Hemel
Samuel Short

INDUSTRY PARTNERS

Vitsoe
M&S
Adnams

FUNDING

EPSRC

HOW TO ENGAGE WITH THE SUSTAINABLE INDUSTRIAL SYSTEMS TEAM

We would be keen to speak to companies who are seeking to explore the challenges of industrial sustainability and discuss how you are preparing for them, and test some of our approaches in your organisation.

If you would like to be involved please contact Dr Dai Morgan (dcm32@cam.ac.uk) or Dr Mike Tennant (m.tennant@imperial.ac.uk).

APPROACH

The project has three key strands –

1. *Developing a deep understanding of the bodies of knowledge that might help develop our understanding of industrial systems, sustainability and the delivery of systemic change.*

2. *Learning with practice, drawing on their experience and tackling complex problems provided by industry partners to improve our understanding of practice and how the industrial system works.*

3. *Developing and testing techniques which draw on the understanding of the literature and practice together to deliver configurations and tools and techniques for using them that will help companies plan for the future.*

The focus in the first year has been on building an understanding of the different bodies of knowledge, early industry engagement and exploring the way that configurations might be developed and used. Future work will focus on the development and testing of prototype tools and techniques, building an understanding of what works what doesn't work and under what circumstances, and the dissemination of results.

A feasible pathway to moving from a linear material flow business model to closed loop business model

This research will seek to understand how companies prepare for the transition to closed loop business models. The research will aims to identify tools and techniques that help companies experiment with scenarios and plan feasible transition pathways.
Lloyd Fernando

How are search partnerships used in the search for innovations?

This research explores how firms search for sustainability-led innovations in collaboration with unusual partners.
Stefan Hemel

Long term planning for sustainable manufacturing using systems thinking

This research seeks to improve the planning processes of companies to better account for the demands and opportunities offered by sustainability and to provide a guide for the transition towards a sustainable industrial system.
Sotirios Levakos

Design of Sustainable Industrial Systems: Organising Principles and Patterns

This research explores the organising principles and patterns of sustainable industrial systems. Drawing insights from systems theory, this work expands the scope of industrial ecology beyond the closing of material loops. This has the potential to foster attributes such as resilience and self-organisation of sustainable industrial systems.
Sudhir Rama Murthy

The Effect of Language on Sustainability Performance

Performance Focusing on metaphors used in discussing issues relating to sustainable development, this research is exploring whether different metaphoric frames can be deployed in order to inspire a more positive, proactive and productive conversation.
Jules Saunderson

Industrial Symbiosis Policy Study in UK and China

This research aims to improve understanding of Industrial Symbiosis practice and practicality from the policy-making perspective of UK and China, exploring the benefits of both 'top-down' and 'bottom-up' approaches.
Yuan Tao

Systemic enablers for radical sustainability-oriented innovation

What are the systemic barriers and enablers to sustainability-driven radical innovation in industry? This research looks at individuals to extract learnings from their practitioner experience.
Ilka Weißbrod

Activities and Outputs

Bodies of knowledge

From circular concepts such as industrial ecology and industrial symbiosis through traditional manufacturing research areas such as supply chain and network studies, the researchers have been exploring subjects that might contribute to the project. Tools from the future studies and transitions literature, and the systems domain have also been explored. In addition to traditional literature reviews the team have also been engaging with systems orientated communities such as the ISIE, ISSSS and SCORAI, and also with thought leaders such as John Ehrenfeld.

Practice engagement

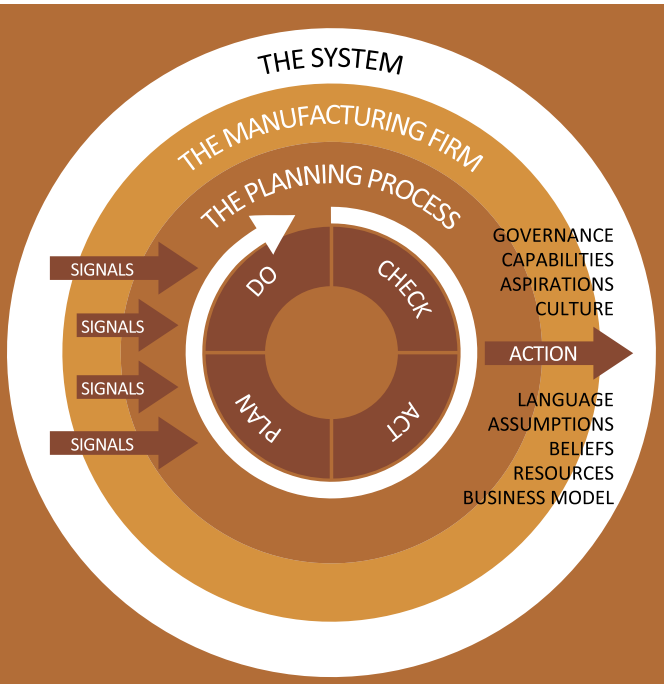
A range of engagements with practice has been pursued; from reviewing industry literature to examine how they express their visions of the future, to student projects, and from interviews with multiple firms, to deep engagement with an individual firm. Geraldine Brennan for example, has attempted to map the industrial ecosystem of a firm who have already tried to close material and energy loops in the business. Her work explores the nature of their relationships with and influence on their industry, customers, staff and community, and how these can be used to deliver value across the system. In a separate

study, Fenna Blomsma has interviewed companies involved in TSB feasibility projects on New Designs For A Circular Economy with the aim of identifying the challenges associated with the work they are doing.

Alongside studies of industrial symbiosis in practice and the conditions that have enabled them, researchers have immersed themselves in communities where those trying to influence change gather, whether that's with groups like the Ellen MacArthur Foundation or the members of the EPSRC Centre. Researchers have also worked with companies to scope out larger industrial issues and will be undertaking a number of projects inspired by real industrial challenges.

Tools & techniques

Early stages of tool and technique development have focussed on how to manage the different sources of configuration. How can practical examples of configurations be compared and assessed? How might theoretically inspired configurations be translated from abstract concepts to practical situations? How do we describe and represent different configurations?



TOOLS & TECHNIQUES - CONFIGURATIONS

Developing configurations – Configurations describe what gets made where and how. Configurations can be inspired by challenges from practice (e.g. what if we got all our products back), by theoretical constructs (e.g. scale free networks) or they might emerge from the application of concepts that offer principles or tools for the future industrial systems (e.g. Cradle to Cradle, Industrial Ecology).

Annual of Configurations - The aim over the next year of activity is to develop a growing body of configurations that will form the basis of interventions with companies, but which are also made publically available to inspire debate.

Prototype tools - Through engagement with industry, prototype tools to help companies work with configurations will be developed, and processes to use them will be developed and tested. These engagements will also begin to provide early indications as to the skills, capabilities and practices manufacturing firms will need to deliver more sustainable industrial systems – this will be shared with the wider industrial and policy communities.

Quick Guides - The tools developed in the project will be augmented by Quick Guides aimed at introducing practical knowledge in the area. Initial quick guides will focus on important foundational concepts such as circular models of production and consumption and the language of sustainability, whilst latter guides will focus on configurations themselves and how they can be used.

Publications

Conference presentation 25-28 June 2013: 7th Biennial Conference of ISIE in South Korea, presentation on the wasted energy of batteries. Yates, M (presented by D Morgan)

Conference Paper, 14-19 July 2013, 57th World Conference of the International Society for Systems Science, Pragmatism, morphogenesis and industrial sustainability, Tennant, M.

Conference Poster, 14-19 July 2013, 57th World Conference of the International Society for Systems Science Industrial sustainability solutions, wisdom or folly? Short, S., Tonelli, F., Raberto, M., Cincotti, S., Fadiran, G.

Conference Poster 14-19 July 2013, 57th World Conference of the International Society for Systems Science, Closed-loop Business Models for Sustainable Manufacturing, Brennan, G. Tennant, M.

Blog Post, Jan 31st, 2013 The Closed Loop or Circular Economy, http://bit.ly/142XDiy

Mini Case Study, AB Sugar: Wissington, http://bit.ly/13qm75y

Book Chapter, The Innovation Handbook 3rd Edition (2013), (Editor Jolly, A.) Finding New Value, Evans S.

STUDENT PROJECTS AS PART OF SUSTAINABLE INDUSTRIAL SYSTEM

PEOPLE INVOLVED

Fiona Gillanders (MET)
Matthew John (CEP)
Roberta Iley (CEP)
Jamie Evans (ISMM)
Michaela Rose (CEP)

OTHER PEOPLE INVOLVED

Dr Dai Morgan
Dr Claire Barlow
Dr Nancy Bocken
Dr Mike Tennant

Sustainable showering – Exploring the options for reducing the life cycle environmental impact of shampoo, focusing on the use phase.

Industrial symbiosis of ice-cream waste – Identifying the value can be extracted from the waste ice-cream generated in businesses.

Developing a framework for multi-level behavior change – How can theories of behaviour change be applied when considering different types of behaviour (e.g. Individual, group, social, cultural).

Circular Economy Toolkit – Developing a toolkit to help companies find opportunities towards a Circular Economy.

Circular Business models – Case study of M&S Shwopping campaign. Reducing the environmental impact of business by developing new business models for the 'Shwopping' program.

OTHER SUSTAINABLE INDUSTRIAL SYSTEMS RELATED PROJECTS

Open Science

PROJECT TEAM

Dr Palie Smart
Dr Sara Holmes

PROGRESS AND OUTPUTS

- *A research paper is being progressed for submission to Research Policy.*
- *A follow-on research proposal is also being drafted.*
- *The outcomes of the study will be discussed with academics from the Research methods division at the American Academy of Management Annual Conference 2013, Orlando, FL, USA*

Traditional Open Science has encouraged a 'cumulative discovery' model through the scholarly publication of research data for the academic communities (knowledge producers). In the present day, a 2nd generation of Open Science (OS2) research practice emerges in which the research community is being re-defined to include multiple stakeholders (i.e. including knowledge users).

As a dynamic system of knowledge production, this project explores the conditions under which Open Science (OS) is an effective approach to research practice for scientific venture.

The project is intended to improve the way in which cross-disciplinary research is conducted through an understanding of the concepts underpinning open science. In developing recommendations for the way Centre partners work together, the project will enable future evaluation of the effectiveness of such recommendations.

TOYOTA ELVS VALUE CHAIN CONFIGURATIONS TO ACHIEVE CIRCULAR ECONOMY STATE

How can an innovative value chain promote a circular economy for End-of-Life Vehicles (ELVs)? This is the question being investigated in a TSB feasibility study. Toyota is addressing this challenge by investigating the opportunities to use innovative configurations of the ELV value chain to keep parts and materials at their highest value and specifications as long as possible. By better understanding the environmental, social and economic implications of such network configurations, this study will provide a strong foundation for Toyota to develop its business plan to move towards a circular economy for the wider benefit of UK society including Toyota customers.

Project Deliverables

- A review of current situation and regulatory context
- A set of options for the future ELVs chain
  - List of parts and materials selected for the study
  - List of actors in the ELVs treatment system
  - List of possible configurations
- A basic model for configuration performance assessment to evaluate the technical feasibility as well as potential benefits and challenges of each option
- List of key variables and success factors
- Basic foundations for a circular economy business plan

PROJECT TEAM

Prof Steve Evans
Dr Mélanie Despeisse
Thomas Rosselle (TGB)
Steve Hope (TME)
Charles Cocoual (TME)

OTHER PHDS ASSOCIATED WITH SUSTAINABLE INDUSTRIAL SYSTEMS

The environmental implications of single-use medical device disposal: an assessment of current practice and potential improvements

This research is focused on the end-of-life options for single-use medical devices and the environmental implications of the different routes available. This will be used to provide guidelines to hospitals on environmentally conscious disposal practices.
Madeleine Yates

Role of informal sector in the solid waste management of developing countries

This project aims at understanding and quantifying the role of the informal sector in solid waste management in developing countries with case studies focusing on two cities of Pakistan. The project is expected to bring solutions for the possible integration of informal recycling sector with the formal sector providing better collection and recycling rates to the public along with introduction of safe disposal methods.
Maryam Masood

Integrating economic, social, and environmental factors into LCA

The research aim is to assist the business unit that is responsible for sustainability in a company by developing a framework that will support in sustainability informed decision making in the organization.
Ioannis Mastoris

An integrated business model for sustainable supply chain management

The research proposed aims to develop an integrated business model for sustainable supply chain management. The aim of the model is to facilitate the assessment of and collaboration with the supply chain to yield sustainable improvements across supply chain.
Handson Pimenta

A framework for understanding the influence of macro sustainability trends and drivers on corporate strategy: insights from UK and Chinese manufacturing firms

This research explores the challenge manufacturing firms have in evaluating complex issues surrounding sustainability when devising their corporate strategy using technology roadmapping. Case studies from both UK and China inform this research.
Elliot More

POLICY

Industrial sustainability is of growing national interest, with policy initiatives across the globe seeking to improve industrial performance and gain a leadership amongst global competition. The EPSRC Centre is involved both in conducting research on policy and in packaging research outputs to help inform policy. This section details some of the policy activities the Centre researchers are involved in.

UK NATIONAL POLICY

Foresight

Since 1994 the Foresight programme has helped the UK government to think systematically about the future. By combining the latest science and evidence with futures analysis, the programme helps policy makers gain a better understanding of the potential opportunities and challenges that lie ahead.

One of the most recent major projects has been looking into the future of manufacturing out to 2050. Professor Steve Evans, EPSRC Centre Director, has been part of the Lead Expert Group (LEG) guiding the evidence base. With a high level steering group chaired by Business Secretary Vince Cable, the project draws on industry and academic expertise from the UK and abroad to look at the long-term picture for the manufacturing sector, investigating global trends and drivers of change. Dr Mike Tennant of Imperial College London has been a key part of the Foresight exercise in preparing a report on sustainability and its impact on manufacturing in the UK as a part of the evidence base that the LEG draws from in generating its conclusions.

Key to the study is how the UK can maximise these opportunities and provide an evidence base to help policy makers navigate a challenging and uncertain future. The project will help inform policy makers in the Department for Business, Innovation and Skills and a range of other relevant departments and is due to be published in the Autumn 2013.

Foresight is part of the Government Office for Science.

PEOPLE INVOLVED FROM THE CENTRE

Prof Steve Evans
Dr Mike Tennant
Elliot More

Next Manufacturing Revolution (NMR)

NMR is a landmark programme to help UK manufacturers improve their non-labour resource productivity. The NMR report launched in early July identifies the significant untapped opportunities for UK manufacturing in non-labour resource efficiency and outlines a programme of action to address the barriers to uptake. The report, co-authored by Lavery Pennell, the University of Cambridge's Institute for Manufacturing and 2degrees, summarises 12 months of research examining resource efficiency performance compared to international good practice for each sub-sector. It found that while many UK manufacturers have achieved 10 to 15% efficiency gains over the last decade, leading companies have achieved over 50% improvements in the same timeframe. The opportunity was conservatively calculated to be worth £10 billion p.a. in additional profits for UK manufacturers, to create 300,000 new jobs and to reduce CO2e emissions by 24% for the UK manufacturing sector (4.5% of UK's total annual emissions). Wider benefits from the programme also accrue to communities including indirect jobs, greater tax revenues and an improved environment.

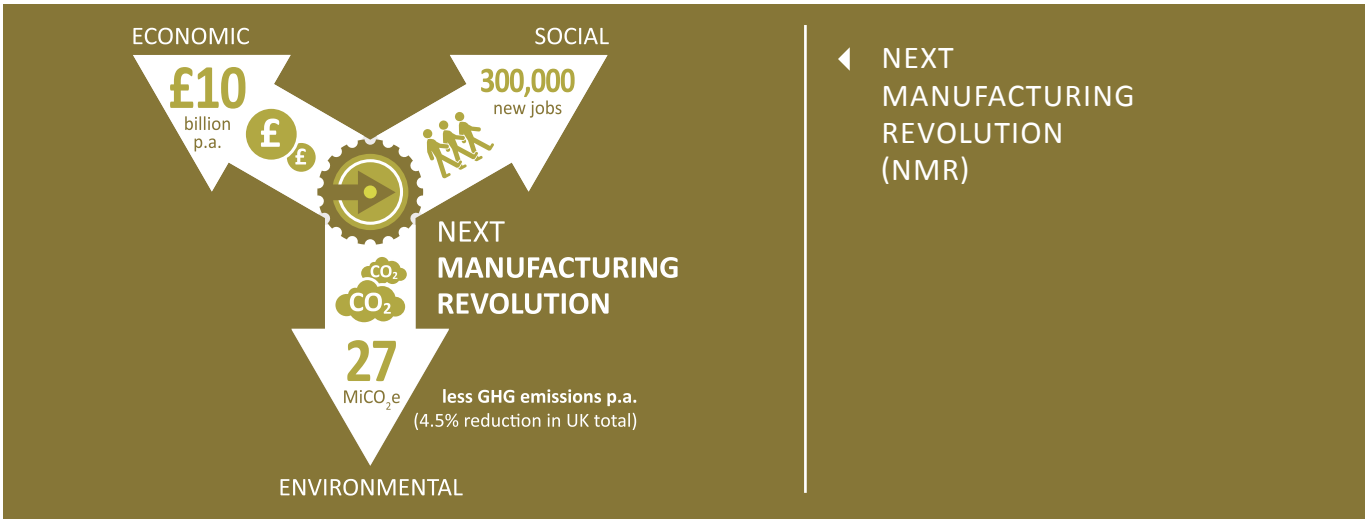
COLLABORATORS

Not-for-profit collaboration between Lavery Pennell, the University of Cambridge's Institute for Manufacturing and 2degrees

PEOPLE INVOLVED FROM THE CENTRE

Prof Steve Evans
Ian Bamford

Find out more about NMR at www.nextmanufacturingrevolution.org.



Based on this research, and supported by case studies from the private sector, NMR has developed a programme to help manufacturing companies realise these benefits, comprising three platforms. The first is the NMR Community, which provides in-depth information, research and interactive information exchange forums, openly accessible to all. The second focuses on Barriers Resolution and Rollout, working collaboratively with experts and manufacturers to overcome industry obstacles that currently prevent the improvement of non-labour resource productivity, through a series of workshops. The third platform is Tailored Support which involves one-to-one advice for manufacturers seeking to identify improvement opportunities within their companies from non-labour resource management.

INTERNATIONAL POLICY AND SUPPORT

UNIDO

Over the past decades, globalisation and industrial development have facilitated high economic growth in several emerging countries, including those in the ASEAN region. Since 1990, the region's GDP has grown more than 5% annually - much faster than the world's average of around 3%. Unfortunately, this economic growth came coupled with a rapid rise in energy demand, high natural resources use, as well as a degradation of the state of the environment. Global energy use has increased by a factor of 13 and material use by a factor of 15 over the last 150 years (Krausmann, 2011).

So far the increase in energy demand has been satisfied mostly by fossil fuels, which contributes to GHG emission increase. While in the past, greenhouse gas emissions emanated mainly from high income countries, today, two amongst five of the highest GHG emitting nations are less developed countries. At the same time, access to energy as a precondition for development remains a major challenge in some parts of ASEAN. Similarly there has been no curb in resource consumption use and few policies enforced to reduce industrial pollution.

In order to deliver what is termed as 'green growth', it is paramount to decouple economic growth from environmental impact. This can be achieved with an integrated framework for supporting the greening of industries, consisting of industry-led initiatives, adoption of best practice technologies, market-based policy instruments and regulations, supported by political support and information flow. However more often than not, the rule of the game is damage limitation in the pursuit of continued economic growth.

In order for UNIDO to make substantial contribution to sustainable development within the industry sector, the Centre needs to facilitate its planning and policy making. This research project proposes a decisive roadmap to change this course of affairs to solidly set ASEAN countries along a sustainable development pathway.

Project objective

Bearing in mind that industrialization has been and still has vast potential for being the engine of growth for the ASEAN region, as long as it does so in a socially and environmentally responsible manner, the main objective of this project is to provide policy recommendations to the ASEAN governing body to facilitate the pursuit of a long-term sustainable development path.

PROGRESS AND OUTPUTS

Two industry reports and a methodology report are currently in preparation.

PROJECT TEAM

Prof Steve Evans
Dr Jae-Hwan Park
Ioannis Mastoris

FUNDING

UNIDO

UN ESCAP

The Ministry of Environment and Green Development of Mongolia requested UN ESCAP to develop a Green Development Roadmap. An expert group meeting in January 2013 suggested development of a "Strategy on Paradigm Change of Water-Energy Resource Management for Business Sector in Mongolia" as a part of the roadmap which will include an overall picture of resource management for business and industry in Mongolia in the context of national development plans.

Project Objectives

The project will develop a conceptual framework on integrated resource management for green development of industries and to propose integrated strategies on how to change the paradigm of integrated resource management to facilitate the development of green business and industries in Mongolia.

PROGRESS AND OUTPUTS

Fieldwork has been completed and policy recommendations are currently being written.

PROJECT TEAM

Prof Steve Evans
Dr Jae-Hwan Park

FUNDING

UNESCAP

IMPROVING DECISION-MAKING CAPACITY AND IMPACT OF SUSTAINABLE DEVELOPMENT IN INDIA

This project involves a of survey the current activity in the social innovation and entrepreneurship ecosystem in India. These for-profit and non-profit enterprises focus on various areas of development services for impoverished communities in urban and rural locales – poverty alleviation, livelihoods, energy and potable water accessibility, public health and education. Research will also be conducted into the current connectivity of networks through the various stakeholders in the ecosystem: investors, government agencies, SMEs, academic institutions and community members themselves. By analyzing primary and secondary research through existing data, gaps in the current ecosystem that impair organizational efficiency and inhibit impact that benefits communities will be identified.

A report will be produced for the Indian government that identifies these gaps and recommends various strategies on how academic institutions and social enterprises can develop partnerships to increase R&D capacity in order to improve impact. Additionally, talks have taken place with the Indian Government's National Innovation Council on developing a national social impact analysis that will be used to evaluate programs that receive government funding.

Following the report, a new capacity-building program for social innovation and entrepreneurship in India will be developed that builds on current work. The program would bring an interdisciplinary research team from the UK, USA and Sweden to collaborate with researchers in India on empirically driven impact analysis. The researchers will work side-by-side with the implementers in communities on monitoring and evaluation protocols to develop the best service models for the organizations and communities through R&D based initiatives.

PROJECT TEAM

Dr Samir K. Doshi
Prof Steve Evans
Dr Padmakshi Rana

PROJECT COLLABORATORS

Digital Green
Vera Solutions
Frontier Markets
Indian Institute of Management in Ahmedabad
Villgro Innovations Foundation
Acumen Fund
Venture Studio

ANNUAL REVIEW

2012-13

COHORT DEVELOPMENT PROGRAMME

> *....I think this event can greatly improve the efficiency of doing PhD since it provides a good opportunity for them to learn from other PhD students with similar research areas.*

Quotes from PhD Researches about the Cohort Programme and Events

ABOUT THE COHORT

The Cohort is a group of doctoral researchers who are working on Centre projects or projects that are related to the broad area of industrial sustainability. The programme aims to bring the researchers together, build future leadership skills, cross functional understanding and personal networks, so ensuring the research PhDs can become influential as they develop beyond the Centre.

The Centre also invites young professionals from member companies to join in the programme and to meet and interact with the researchers, forming professional and social bonds across the group.

The Cohort programme includes events to develop skills such as interview techniques and research methodology and creativity. The network of researchers is encouraged to keep each other up to date with the latest goings on and to gather around the best events across the Universities of the Centre and beyond.

Quotes from PhD Researches about the Cohort Programme and Events

'…it is enlightening and also very encouraging to work with/around people who are within the centre. I was able to be productive (producing one abstract and an extension of PhD subject area for my 9 month review) while also being able to take part in the activities…'

'…as an early stage researcher I needed an opportunity to bring up lots of issues I was having, and this was the perfect environment for that. I got lots of useful feedback from both peers and the lectures.'

'….I think this event can greatly improve the efficiency of doing PhD since it provides a good opportunity for them to learn from other PhD students with similar research areas.'

EVENTS & ACTIVITIES

- ***Appreciate Align and Amplify***
  Workshops for improving creativity and impact, October – December, 2012
- ***Losehill Cohort Development Event***
  3-7th December 2012, Losehill Hall YHA Peak District.
- ***Cohort Reps Elected and Introduced to Executive***
  January
- ***Cohort Away Day at Cambridge***
  Featuring meetings with researchers and Lecture from Tim Jackson @ the distinguished lecture series held by the MPhil in Engineering for Sustainable Development March 20th 2013
- ***Cohort Interview Training Day***
  Institute for Manufacturing, Featuring sessions from 10 Centre staff introducing key concepts in interview technique.
- ***Research Methodology Workshop***
  Institute for Manufacturing
- ***Communicating and selling ideas and conference support pack***
  Summer 2013

ANNUAL REVIEW

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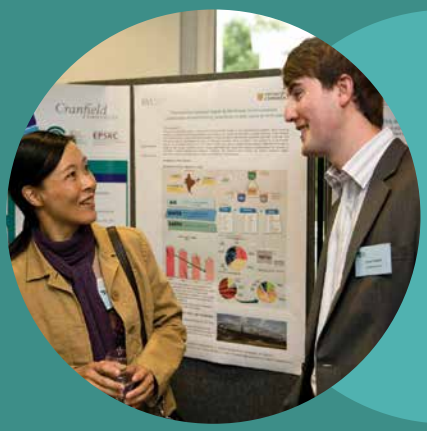

CENTRE OUTREACH ACTIVITIES

ENGAGEMENT WITH INDUSTRY AND THE SUSTAINABILITY COMMUNITY

Annual Conference

In September 2013 the EPSRC Centre will hold its second annual conference 'Integrating Industrial Sustainability' in Cambridge. The conference will look in to the ways in which Industrial Sustainability has been and needs to be integrated and will explore five themes: Balancing across practice boundaries; Integrating across the Factory; Integrating different levels of business capability; Integrating current and future needs; and, Next Manufacturing Revolution. This two day event will include talks from Peter Price Thomas, Senior Associate and former CEO of The Natural Step and Dr John Ehrenfeld, Author of 'Sustainability by Design' and Director of the International Society for Industrial Ecology. Over 100 delegates are expected to attend the conference by invitation including members of industry and academia.

ANNUAL CONFERENCE THEMES

1. *Balancing across practice boundaries*
2. *Integrating across the Factory*
3. *Integrating different levels of business capability*
4. *Integrating current and future needs*
5. *Next Manufacturing Revolution.*

Next Manufacturing Revolution at the Palace of Westminster

On July 16 2013 the Next Manufacturing Revolution (NMR) launched its landmark report and programme to help UK manufacturers improve their non-labour resource productivity. The report identifies the significant untapped opportunities for UK manufacturing in non-labour resource efficiency and outlines a programme of action to address the barriers to uptake. At the launch in the Palace of Westminster, the Rt Hon Gregory Barker MP and Professor Steve Evans spoke of the timeliness of this initiative while Steve Adams from Coca Cola Enterprises and Inder Poonaji from Nestle gave examples of their companies' pioneering resource efficiency. Find out more information about NMR in the policy section of this report or at www.nextmanufacturingrevolution.org.

NEXT MANUFACTURING REVOLUTION REPORT

Find out more information about NMR in the policy section of this report or at ***www.nextmanufacturingrevolution.org.***

Member Meetings

The Centre held an entertaining Member Meeting at the Natural History Museum on 18th January, despite the threat of disruptive weather there was a very good attendance. The members particularly liked the opportunity to discuss projects in detail with the researchers and several new directions were identified and new project ideas initiated. There was also the opportunity to discuss the tools and guides that were under development with positive and constructive feedback provided from the members leading to changes in the style, content and in some cases structure of those in development and planned. Members also offered some tools that the Centre could adapt and share with the wider manufacturing community. Information was shared regarding how best to engage with the Centre Universities student projects, which resulted in a strong uptake of student projects at members such as Toyota, Unilever, Vitsoe, throughout the year.

Webinars

Following the success of last year's webinar program, the EPSRC Centre hosted another series of eight webinars from November 2012 through April 2013 to facilitate communication on Centre research projects across the four Centre locations and to members. Topics included: An introduction to a Library of sustainable manufacturing practices; The impact of language on performance; Developing business models for a closed loop economy; Eco-intelligent Factories; Responsible Innovation; Sustainable design for product service systems; Factory modelling; and, Configurations for Sustainable Industrial Systems. Copies of the talks can be downloaded from the Centre website. Webinars were also conducted in conjunction with iema to their audience of iema members.

WEBINAR TOPICS

- *An introduction to a Library of sustainable manufacturing practices*
- *The impact of language on performance*
- *Developing business models for a closed loop economy*
- *Eco-intelligent Factories*
- *Responsible Innovation*
- *Sustainable design for product service systems*
- *Factory modelling*
- *Configurations for Sustainable Industrial Systems.*

ENGAGEMENT WITH THE INTERNATIONAL SUSTAINABILITY COMMUNITY

JAPANESE ACADEMICS

Prof Hiroyuki Yoshikawa
Director-General, Center for Research and Development Strategy, Japan Science and Technology Agency

Prof Tomonari Yashiro
The University of Tokyo

Prof Kanji Ueda
Special Adviser of the National Institute of Advanced Industrial Science and Technology

Prof Takahiro Fujimoto
The University of Tokyo

Prof Shozo Takata
Wasda University

Dr Tomomi Kito
The University of Tokyo and Saïd Business School, Oxford

UK-Japan Industrial Sustainability Workshop and Public Seminar

In July 2013 Professor Sir Mike Gregory (Cambridge), Professor Steve Evans (Cambridge), Dr Ritsuko Ozaki (Imperial College) and Dr Peter Ball (Cranfield) from the EPSRC Centre and Professor Chris France of the University of Surrey participated in a UK-Japan Industrial Sustainability Workshop and Public Seminar organised by the UK Embassy in Tokyo. The focus of the workshop was on the long term research, policy and industrial agendas that support the re-shaping of the industrial system to be sustainable. The workshop was be a bilateral session consisting of presentations and discussions to identify collaboration areas and set the way forward. A similar event was held at the Embassy in 2011 when discussions focused on what can be achieved in the short and medium term. The UK group were joined by their Japanese colleagues Professor Hiroyuki Yoshikawa (Director-General, Center for Research and Development Strategy, Japan Science and Technology Agency), Prof Tomonari Yashiro (The University of Tokyo), Professor Kanji Ueda (Special Adviser of the National Institute of Advanced Industrial Science and Technology), Prof Takahiro Fujimoto (The University of Tokyo), Professor Shozo Takata (Wasda University), and Dr Tomomi Kito (The University of Tokyo and Saïd Business School, Oxford).

The workshop was followed by a public seminar to showcase the UK's expertise and research capabilities in sustainable manufacturing to a Japanese audience. Professor Gregory, Professor Evans, Professor France, and Professor Fujimoto gave presentations at the seminar.

Chinese Delegation Visits the Centre for Industrial Sustainability and the IfM

In June 2013 a delegation from the Beijing Environmental Protection Bureau led by Mr Chen Tian - Director General, visited the IfM. They were particularly interested to understand how Cambridge and the IfM in particular could assist them in some of the problems that air pollution raises in Beijing. EPSRC Centre for Industrial Sustainability staff organised a series of presentations to delegation from: Dr Martin Garratt, CEO of Cambridge Cleantech; Professor Douglas Crawford Brown, Director Cambridge Centre for Climate Change Mitigation; Mr Jailun Hu, PhD student from the Centre for International Manufacturing (CIM) at the IfM; Dr Mélanie Despeisse, Lead Researcher at the Centre for Industrial Sustainability; and Mr Ian Bamford, Commercial Director of the Centre for Industrial Sustainability.

ENGAGMENT WITH THE WIDER PUBLIC

Web Presence

The Centre has a comprehensive public website providing detailed information on Centre activities including the research agenda and projects, the people, membership program, news and events, and careers. Behind the public interface is a series of private project forums which allow collaborative work to take place between the members of each project team. The website is expected to expand over the next year with the inclusion of a library of Centre publications and the addition of social media functionality.

EXECUTIVE GROUP

Prof Steve Evans
(Chairman)
University of Cambridge

Prof Shahin Rahimifard
Loughborough University

Prof Sir Mike Gregory
University of Cambridge

Dr Peter Ball
Cranfield University

Dr Mike Tennant
Imperial College, London

Ian Bamford
University of Cambridge

Dr Richard Bailey
EPSRC

Jorge Arinez
GM

Hugo Spowers
Riversimple

Steve Hope
Toyota Motor Europe

Roy Willey
Unilever

Dr Derek Pedley
ESKTN

HIGH LEVEL GROUP

Barry Sheerman MP
(Chairman)

Andrew Buckley
Membership Director, EEF

Tim Page
Senior Policy Officer, TUC

Dr Stephan Biller
Chief Manufacturing Scientist, GE Global Research

Prof Günther Seliger
Chair of the Collaborative Research Centre 281, TU Berlin

Prof Adisa Azapagic
Professor of Sustainable Chemical Engineering, The University of Manchester

Lynva Russell
Chief Executive, PolicyConnect

Richard Miller
Head of Sustainability, TSB

Paul Calver
Sector Specialist - Advanced Manufacturing Strategic Trade Group, UKTI

William Butler-Adams
Managing Director, Brompton Bicycle Ltd

Andrew Churchill
Managing Director, JJ Churchill

Steven Fawkes
Day One Energy Solutions, Chairman Bglobal Plc, NED

COLLABORATORS

CLAAS
ELCON Solution Oy
FIDIA S.p.A.
Luxottica
Airbus
Digital Green
Vera Solutions
Frontier Markets
Indian Institute of Management in Ahmedabad
Villgro Innovations Foundation
Acumen Fund
Venture Studio
ASICS
Cambridge Programme for Sustainability Leadership (CPSL)
Angelantoni (Archemedes Solar)
Stanley-DeWalt Italia
Campari
Colacem
CSC
Cucchinelli
Dupont
ILVA
Loccioni
Umbra Group
Veragon
AB Sugar
Boots
Kyocera
Xeros
Lavery Pennell
2degrees
VTT Technical Research Centre of Finland
Politecnico di Milano
University of Stavanger
RWTH Aachen University
DIN, The German Institute for Standardization
University of Genova

EPSRC Centre
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